TARGET RECOGNITION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

5   This application claims priority of Japanese Patent
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BACKGROUND OF THE INVENTION

Field of the Invention

        The present invention relates to a target
10   recognition apparatus. The invention particularly
relates to a target recognition apparatus that measures a
distance from a vehicle to a target, based on parallax
information from two images of the target simultaneously
picked up by two cameras (a left camera and a right
15   camera) that are mounted on the vehicle, with a
predetermined distance between the cameras in a
horizontal direction.

Description of the Related Art

        Conventionally, there has been known a target
20   recognition apparatus that measures a distance from a
vehicle to a target, based on parallax information from
of target images picked up by two cameras that are
mounted on the vehicle at positions at the same height
above ground level, with a predetermined distance between
25   the cameras. Generally, this kind of target recognition
apparatus generates edge images by carrying out an edge
extraction processing to an input left image that is
input after the left camera has picked up this image, and
an input right image that is input after the right camera
30   has picked up this image. The target recognition
apparatus measures a distance to the target, based on a
parallax between the corresponding edge positions in the
two edge images.

        A filter that passes only vertical components of the
35   photographed images is used as an edge extracting filter
that carries out an edge extraction processing of the
photographed images. Therefore, when a vehicle has an

angular shape, it is easy to extract both end portions of
the vehicle as edges. However, when a vehicle has a
curved surface on the side surface and has a relatively
round cross-sectional shape, it is difficult to detect
5   vertical components, and thus, it is difficult to extract
edges.

     Further, when cameras that can pick up images of a
wide-angular range are used, a photographed vehicle
appears to have a round shape even if the vehicle has
10   actually an angular shape with many vertical components.
This is due to a distorted astigmatism. Therefore, it
becomes difficult to extract edges. As explained above,
when a target that has curves at both end portions is
photographed, edges at the ends of the target do not
15   always appear on the photograph, even if the edge
extraction processing is carried out on the photographed
target. Therefore, it is not easy to specify both ends
of the target, that is, a width of the target.

20   SUMMARY OF THE INVENTION

     The present invention has been made in the light of
the above problems. It is, therefore, an object of the
present invention to provide a target recognition
apparatus that can improve a recognition rate of a target
25   by emphasizing vertical components, even if a cross-
sectional shape of the target is round, and it is
difficult to extract edges at both ends of the target.

     A target recognition apparatus of the present
invention that achieves the above object is a target
30   recognition apparatus that measures a distance from a
vehicle to a target. The target recognition apparatus
comprises: two cameras that are mounted on the vehicle at
positions at the same height above ground level, with a
predetermined distance between the cameras; an image
35   compressing unit that compresses an image in at least a
lateral direction, for each of a left image and a right
image that are input after the images are picked up

simultaneously with the two cameras; a target detecting unit that detects both ends of the target in each of the left image and the right image, based on gradations of pixels in the images that have been compressed in at least a lateral direction; and a distance measuring unit that measures a distance to the target, based on a parallax of the both detected ends of the target.

The image compressing unit of the target recognition apparatus according to the present invention can have the following modes.

(1) The image compressing unit compresses the images in only a lateral direction.

(2) The image compressing unit compresses the images in a lateral direction, and also compresses the images in a vertical direction at a smaller compression rate than the compression rate of the images in a lateral direction.

(3) The image compressing unit compresses the images in a lateral direction, by extracting pixels of the images in a lateral direction at every predetermined plurality of pixels.

(4) The image compressing unit compresses the images in a lateral direction, by putting pixels that continue in a lateral direction in the images into groups of pixels, each group having a predetermined plurality of pixels, and by extracting a pixel that has a maximum gradation among pixels in each group.

(5) The image compressing unit compresses the images in a lateral direction, by putting pixels that continue in a lateral direction in the images into groups of pixels, each group having a predetermined plurality of pixels, and by extracting a pixel that has a minimum gradation among pixels in each group.

(6) The image compressing unit puts pixels that continue in a lateral direction in the images into groups of pixels, each group having a predetermined plurality of pixels, compresses the images in a lateral direction by

setting each group as one pixel, and fixes a gradation of this one pixel as an average value of gradations of pixels in each group.

(7) The image compressing unit puts pixels that continue in a lateral direction in the images into groups of pixels, each group having a predetermined plurality of pixels, compresses the images in a lateral direction by setting each group as one pixel, and fixes a gradation of this one pixel as a total sum of gradations of pixels in each group.

(8) The image compressing unit puts pixels that continue in a lateral direction in the images into groups of pixels, each group having a predetermined plurality of pixels, compresses the images in a lateral direction by setting each group as two pixels, and extracts a maximum value and a minimum value of gradations of pixels in the order of appearance in each group, as gradations of the two pixels.

(9) The image compressing unit puts pixels that continue in a lateral direction in the images into groups of pixels, each group having a predetermined plurality of pixels, compresses the images in a lateral direction by setting each group as two pixels, and extracts two gradations between which there is a largest change in each group, as gradations of the two pixels.

Further, the target recognition apparatus of the present invention can further comprise a searching area setting unit that sets a target searching area to images that have been compressed by the image compressing unit.

Further, the searching area setting unit can set a searching area in the following methods.

(A) The searching area setting unit sets a whole surface of an image as a target searching area.

(B) The searching area setting unit sets a lane on which the vehicle runs as a target searching area.

(C) The searching area setting unit sets an area to which the vehicle proceeds as a target searching area.

(D) The searching area setting unit sets a target searching area based on an area in which the target detecting unit has both detected ends of a target last time.

(E) The searching area setting unit sets an area in which another decision unit has decided that there is a possibility of existence of a target, as a searching area.

Further, the target detecting unit of the present invention can have the following operation modes.

(a) The target detecting unit detects both ends of a target by detecting edges.

(b) The target detecting unit detects a range in a lateral direction in which a variance in added values of gradations in a vertical direction is not larger than a constant value, as an existence position of a target.

(c) The target detecting unit detects a position in a lateral direction at which an added value of gradations in a vertical direction exceeds a constant value, and a position in a lateral direction at which the added value is less than the constant value, as both ends of a target.

(d) The target detecting unit detects a range in a lateral direction in which a variance in average values of gradations in a vertical direction is not larger than a constant value, as an existence position of a target.

(e) The target detecting unit detects a position in a lateral direction at which an average value of gradations in a vertical direction exceeds a constant value, and a position in a lateral direction at which the average value is less than the constant value, as both ends of a target.

According to the present invention, an S / N ratio is improved and vertical components are emphasized, by compressing the images picked up with cameras in a lateral direction, thereby to improve a recognition rate of a target. Based on this, it becomes possible to

stabilize the performance of measuring a distance by the target recognition apparatus, which it has been difficult to achieve in the past due the shapes of vehicles. Further, it becomes possible to shorten the processing time. It is possible to further shorten the processing time by limiting a searching area.

SUMMARY OF THE INVENTION
     The present invention will be more clearly understood from the description as set forth below with reference to the accompanying drawings.
Fig. 1 shows diagrams that are left and right input images and edge images corresponding to these images. (A) shows an input left image picked up with a left camera, (B) shows an input right image picked up with a right camera, (C) shows an edge image of (A), and (D) shows an edge image of (B).
     Fig. 2 is a block diagram that shows a hardware structure of a target recognition apparatus according to one embodiment of the present invention.
     Fig. 3A shows an input image that is picked up with one camera.
     Fig. 3B shows an edge image obtained by carrying out an edge processing to the input image of Fig. 3A.
     Fig. 4 shows diagrams that explain calculation of parallax based on left and right edge images that are extracted from left and right input images. (A) shows an input left image, (B) shows an input right image, (C) shows a left edge image, and (D) shows a right edge image.
     Fig. 5A shows an input image that is picked up with one camera.
     Fig. 5B shows an image compressed in a lateral direction, obtained by carrying out an image lateral-direction compression processing to the input image shown in Fig. 5A.
     Fig. 5C is a diagram of level values that show

gradation levels of pixels that exist in a frame P0 of the image shown in Fig. 5A, in numerical values from 0 to 255.

Fig. 5D is a diagram that shows an enlarged image of a part of an image before the compression, to facilitate the understanding of pixels.

Fig. 5E is a diagram that shows an image obtained by compressing the image of Fig. 5D in a lateral direction.

Fig. 6 is a diagram that explains a first method of compressing an image in a lateral direction.

Fig. 7 is a diagram that explains a second method of compressing an image in a lateral direction.

Fig. 8 is a diagram that explains a third method of compressing an image in a lateral direction.

Fig. 9 is a diagram that explains a fourth method of compressing an image in a lateral direction.

Fig. 10 is a diagram that explains a fifth method of compressing an image in a lateral direction.

Fig. 11 is a diagram that explains a sixth method of compressing an image in a lateral direction.

Fig. 12 is a diagram that explains a seventh method of compressing an image in a lateral direction.

Fig. 13 is a diagram that explains a first method of setting a searching area.

Fig. 14 is a diagram that explains a second method of setting a searching area.

Fig. 15 is a diagram that explains a third method of setting a searching area.

Fig. 16 is a diagram that explains a fourth method of setting a searching area.

Fig. 17 is a diagram that explains a fifth method of setting a searching area.

Fig. 18 is a diagram that explains a method of detecting both ends of a target by extracting edges.

Fig. 19 is a diagram that explains a method of detecting both ends of a target based on an added value of gradations in a vertical direction.

Fig. 20 is a diagram that explains a method of detecting both ends of a target based on an average value of gradations in a vertical direction.

5   DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before describing the preferred embodiments, an explanation will be given of a conventional target recognition apparatus shown in Fig. 1.

Two cameras are installed on a vehicle at positions
10   from which it is possible to look through the front of the vehicle. The cameras are positioned at the same height, with a predetermined distance between the cameras. When the two cameras photograph the front view while the vehicle is running on a three-lane road, two
15   images, as shown in Figs. 1 (A) and (B), are obtained. When a target vehicle is running in front of the vehicle at this time, this vehicle running in the front is photographed as the target in the two images. When an edge extraction processing is carried out to the image
20   (A), an edge image as shown in (C) is generated. When an edge extraction processing is carried out to the image (B), an edge image as shown in (D) is generated.

In comparing the image of (C) with the edge image of (D) in Fig. 1, it can be understood that a parallax
25   exists between these images. According to the conventional target recognition apparatus using two cameras, the apparatus measures a distance to the target based on parallax information in the edge images.

As an edge extraction filter that carries out this
30   type of edge extraction processing, a filter that passes only vertical components is generally used. Therefore, when a vehicle has a relatively round shape by having a side surface structured in curves, it is not easy to obtain edges. Further, when cameras having wide-angle
35   lenses are used, picked-up images of a vehicle appear round although the vehicle has actually an angular shape. Therefore, it becomes difficult to extract edges. As

explained above, according to the conventional target
recognition apparatus, it has not always been possible to
obtain edges at ends of a target, even when an edge
processing is carried out to the picked-up images.
5   Therefore, there has been a problem that it is difficult
to specify both ends of a target, that is, a width of a
target.

        The present invention has been made in the light of
the above problems of the conventional target recognition
10   apparatus. Structures of embodiments of a target
recognition apparatus according to the present invention
will be explained below.

        Fig. 2 is a block diagram that shows a hardware
structure of a target recognition apparatus 30 relating
15   to one embodiment of the present invention. A left
camera 22 and a right camera 24 are installed at
positions at the same height above ground level on a
vehicle, with a predetermined distance between the
cameras. The left camera 22 and the right camera 24
20   incorporate image pick-up devices like charge-coupled
devices (CCD) respectively. Images picked up with these
cameras 22 and 24 are output as electric signals
corresponding to the numbers of pixels of the image pick-
up devices. The input image signals from the left camera
25   22 and the right camera 24 are input to a digital signal
processor (DSP) 36 via corresponding image signal
receiving circuits 32 and 34 respectively. The images
are stored in a static RAM 38.

        The DSP 36 executes lateral-direction compression
30   processing, to be described later, on the left image and
the right image stored in the static RAM 38, and executes
edge extraction processing on these compressed images,
thereby to generate left and right edge images. The DSP
36 transmits parallax information, on edges corresponding
35   to the left and right edge images, to a microcomputer 40.

        The microcomputer 40 calculates and obtains a
distance to the target from this parallax information.

Next, the microcomputer 40 transmits the obtained target recognition information to a vehicle control unit 52 that carries out a support and risk avoidance operation, and an alarm unit 54 that can notify a driver.

Fig. 3A shows one example of an input image that is picked up with one of the cameras mounted on the vehicle, and is input to the target recognition apparatus 30. In the example shown in Fig. 3A, three vehicles are running in front of the camera, and these vehicles become targets. This input image is a group of pixels corresponding to the number of pixels of the image pick-up device. When edge extraction processing for differentiating gradations of the pixels in a lateral direction is carried out on the input image shown in Fig. 3A, an edge image shown in Fig. 3B is obtained. The edge extraction processing is carried out to both the left image and the right images that are the input images.

Fig. 4 shows input images and edge images of the same status as that of Fig. 3A picked up with two cameras. (A) shows an input left image, (B) shows an input right image, (C) shows an edge image of (C), and (D) shows an edge image of (B). Calculation of parallax based on the left and right edge images that are extracted from the left and right input images will be explained. A peak position and peak power of a characteristic point are extracted from the edge images shown in (C) and (D) respectively. Next, a parallax is calculated for the characteristic point (each peak).

It is not always possible to obtain edges at ends of a target as described above. Therefore, it is not easy to specify both ends of the target, that is, a width of the target. In the present invention, an S / N ratio of an image is improved and vertical components are emphasized, by using images compressed in a lateral direction, thereby to improve a recognition rate of a target.

A reason why the S / N ratio improves when edge

extraction is carried out by using images compressed in a lateral direction will be explained. When an edge extraction is carried out using a non-compressed image, an edge image as shown in Fig. 3B is obtained. At the

5   time of extracting a characteristic point to specify a vehicle position and a vehicle width, this work receives the influence of noise other than a target, for example, noise components of a background and the like, when a non-compressed image is used. Consequently, it becomes

10   difficult to extract edges. However, when the obtained image is compressed in a lateral direction in order to reduce the noise components, irregular noise components can be cut, and the S / N ratio improves. The actual vehicle components remain even after a compression of the

15   image in a lateral direction. Therefore, it becomes possible to extract edges.

    Examples of compressing an image in only a lateral direction will be explained below. However, the present invention is not limited to these examples. The present

20   invention also includes a method of compressing an image to both a lateral direction and a vertical direction, at a compression rate in a lateral direction larger than a compression rate in a vertical direction. In other words, the present invention also includes a method of

25   compressing an image in a vertical direction but at a smaller compression rate than a compression rate of compressing the image in a lateral direction.

    Fig. 5A to Fig. 5E are diagrams for explaining an image lateral-direction compression processing. In the

30   embodiment of the present invention, an input image shown in Fig. 5A is transformed to an image compressed in a lateral direction as shown in Fig. 5B, before an edge extraction processing is carried out. In this example, an image that has 480 pixels in a vertical direction and

35   640 pixels in a lateral direction is compressed to a quarter in only the lateral direction. As a result, the compressed image has 480 pixels in a vertical direction

and 160 pixels in a lateral direction.

In the case of a normal image shown in Fig. 5A, both ends of a vehicle are round as shown at a portion P1. When the image is compressed as shown in Fig. 5B, both ends of the vehicle are close to vertical as shown at a portion P2. Therefore, it becomes possible to carry out a stable recognition of the target, without being affected by the shape of the vehicle (particularly, a rounded vehicle having curves on the side surface of the vehicle). Several methods are considered for the compression processing in a lateral direction.

Assume that a part of an area P0 shown by a square in the image of Fig. 5A is constructed of pixels schematically shown in Fig. 5C. A compression method will be explained taking this portion as an example. Although Fig. 5A shows the area P0 as if there exists a plurality of pixels in its vertical direction in the width, there is actually only one pixel in a vertical direction in the area P0. Fig. 5C shows gradations of pixels at respective pixel positions, when there are 19 pixels in a lateral direction at a part of the area P0. The gradations of the pixels take a value range from 0 to 255. The gradation of a pure white pixel that has no image has a value 0, and the gradation of a black pixel has a value 255.

When the image is compressed in a lateral direction, for example, an image that has pixels in a layout convex to the right as shown in Fig. 5D becomes an image that is compressed in a lateral direction as shown in Fig. 5E. The pixels of the target that exist with a variance of four to five pixels in a lateral direction are put together in one pixel in a lateral direction. As a result, vertical components can be emphasized.

Fig. 6 is a diagram that explains a first method of compressing an image in a lateral direction. The upper row shows gradations of a normal image, and the lower row shows gradations after the image has been compressed in a

lateral direction. In the first method, gradations of
pixels are extracted at every predetermined plurality of
pixels in a lateral direction. In the example shown in
Fig. 6, the image compressed in a lateral direction is
5   prepared by obtaining data of every four pixels.

Fig. 7 is a diagram that explains a second method of
compressing an image in a lateral direction. In the
second method, a predetermined plurality of pixels that
continue in a lateral direction are collected as one
10   group, and a maximum value of gradations is extracted in
each group. In the example shown in Fig. 7, four pixels
are collected as one group, and the image compressed in a
lateral direction is prepared by obtaining a maximum
value data in each group. At night, the total image
15   becomes dark, in a tunnel or the like. In this case, it
becomes easy to specify a target when a maximum value
data is employed in this method.

Fig. 8 is a diagram that explains a third method of
compressing an image in a lateral direction. In the
20   third method, a predetermined plurality of pixels that
continue in a lateral direction are collected as one
group, and a minimum value of gradation is extracted in
each group. In the example shown in Fig. 8, four pixels
are collected as one group, and the image compressed in a
25   lateral direction is prepared by obtaining a minimum
value data in each group. In daytime, when the total
image becomes bright, it becomes easy to specify a target
by employing a minimum value data.

Fig. 9 is a diagram that explains a fourth method of
30   compressing an image in a lateral direction. In the
fourth method, a predetermined plurality of pixels that
continue in a lateral direction are collected as one
group, and an average value of gradations is extracted in
each group. In the example shown in Fig. 9, four pixels
35   are collected as one group, and the image compressed in a
lateral direction is prepared by obtaining an average
value data in each group. When an average value data is

employed, it becomes possible to absorb a variance in an image.

Fig. 10 is a diagram that explains a fifth method of compressing an image in a lateral direction. In the fifth method, a predetermined plurality of pixels that continue in a lateral direction are collected as one group, and a total sum of gradations is extracted in each group. In the example shown in Fig. 10, four pixels are collected as one group, and the image compressed in a lateral direction is prepared by obtaining a total sum in each group. According to the above average value data, there is an inconvenience in that a setting range of a threshold value for specifying a target in the latter-stage processing becomes narrow. On the other hand, it becomes easy to set a threshold value when a decision is made based on a total sum.

Fig. 11 is a diagram that explains a sixth method of compressing an image in a lateral direction. In the sixth method, a predetermined plurality of pixels that continue in a lateral direction are collected as one group, and a maximum value and a minimum value of gradations are extracted in the order of appearance in each group. In the example shown in Fig. 11, eight pixels are collected as one group, and the image compressed in a lateral direction is prepared by obtaining a maximum value and a minimum value in each group. According to this method, it becomes possible to specify a target without being affected by bright or dark images, when a decision is made using maximum value and minimum value data at the same time.

Fig. 12 is a diagram that explains a seventh method of compressing an image in a lateral direction. In the seventh method, a predetermined plurality of pixels that continue in a lateral direction are collected as one group, and two gradations between which there is a largest change in each group are extracted. In the example shown in Fig. 12, eight pixels are collected as

one group, and the image compressed in a lateral
direction is prepared by obtaining values of two adjacent
pixels. It becomes easy to recognize a target at a final
stage, by understanding a change quantity of gradations
at the compression time.

When the above image compression processing in a
lateral direction is carried out in advance, it becomes
easy to shorten the time required for the target
recognition procession at a later stage. In order to
further shorten this time, it is preferable to set a
target searching area to the compressed image. Fig. 13
to Fig. 17 show methods of setting a searching area to
the compressed image.

A first setting method is a method of setting a
whole surface of an image compressed in a lateral
direction, as a searching area of a target, as shown in
Fig. 13.

A second setting method is a method of setting a
lane (an area encircled with white lines) in which a
vehicle mounted with a target recognition apparatus of
the present invention runs, as a searching area of a
target, as shown in Fig. 14.

A third setting method is a method of setting a
triangular area in a vehicle proceeding direction, as a
searching area of a target, as shown in Fig. 15.

A fourth setting method is a method of setting an
area in which both ends of a target have been detected
last time by a target detection processing to be
described later, as a searching area of a target, as
shown in Fig. 16. In this case, it is preferable to set
a range slightly larger than the area in which both ends
of a target have been detected last time, as the
searching area.

A fifth setting method is a method of setting an
area in which an edge-extraction decision unit has
decided that there is a possibility of the existence of a
target from an edge image prepared based on an image

compressed in a lateral direction, as a searching area, as shown in Fig. 17.

According to the present invention, the DSP 36 explained with reference to Fig. 2 carries out a target detection processing that detects both ends of a target based on gradations of pixels, in the images compressed in a lateral direction, or in the searching areas that have been set to the images according to the first to fifth setting methods.

For the target detection processing, there is a method of detecting both ends of a target by carrying out the edge extraction as shown in Fig. 18.

Further, as shown in Fig. 19, it is also possible to detect a range in a lateral direction in which a variance in added values of gradations in a vertical direction is not larger than a constant value, as an existence position of a target. However, it is necessary to obtain values of a road surface in advance based on a background processing, and exclude the road surface.

Alternately, as shown in Fig. 19, it is possible to recognize a position in a lateral direction at which an added value of gradations in a vertical direction exceeds a reference value (10000 in this drawing), as the body of the vehicle running in the front, and detect positions in a lateral direction at which this value is lowered from an area in which this value exceeds the reference value to an area in which this value is less than the reference value, as both ends of the target.

Further, as shown in Fig. 20, it is also possible to detect a range in a lateral direction in which a variance in average values of gradations in a vertical direction is not larger than a constant value, as an existence position of a target. However, it is necessary to obtain values of a road surface in advance based on a background processing, and exclude the road surface.

Alternately, as shown in Fig. 20, it is possible to recognize a position in a lateral direction at which an

average value of gradations in a vertical direction
exceeds a reference value (100 in this drawing), as a
body of the vehicle running in the front, and detect
positions in a lateral direction at which this value is
5   lowered from an area in which this value exceeds the
reference value to an area in which this value is less
than the reference value, as both ends of the target.

        In the case of detecting an existence position and
both ends of a target according to the processing
10 explained with reference to Fig. 19 or Fig. 20, it is
preferable to provide a constant margin and detect a
target in a slightly larger range, thereby to increase
the stability.